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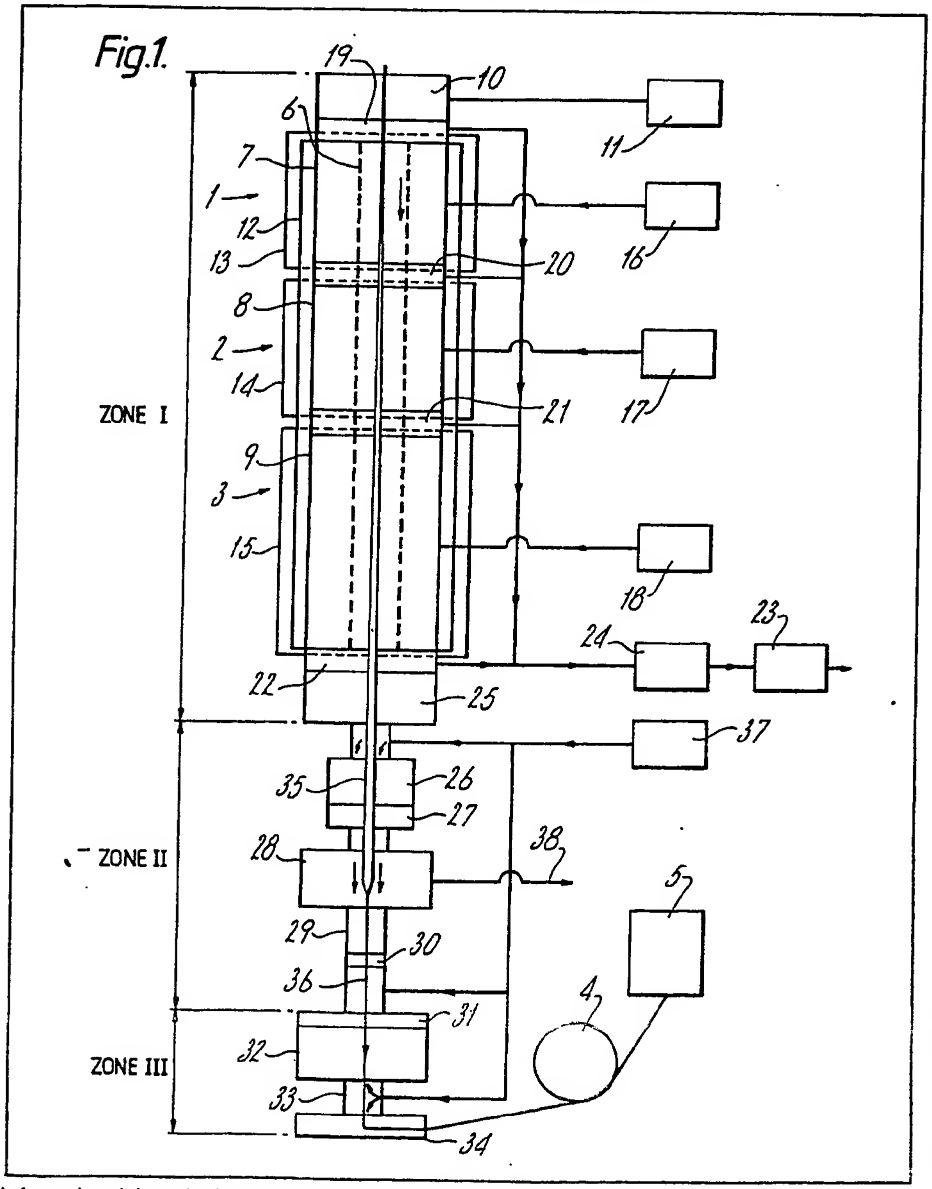
(54) Continuous process for manufacture of optical fibre waveguides

(57) An elongate glass seed core is fed successively through a deposition zone (I) in which a glass coating, or two or more successive glass coatings, is or are deposited on the seed, by annular chemical vapour deposition effected continuously along the whole length of seed in each section of the zone, and through a drawing zone (II) in which the preform (35) so formed is heated and drawn to fibre (36) which may then be resin-coated in zone III. Deposition zone (I) comprises an outer tube (or two or more outer tube sections 7,8,9) into which vapour-phase reactants are fed, and inner perforated tube 6 within which coat-forming reactions are activated e.g. by a plasma, a laser beam, and/or external heating, and/or gas combustion within the reaction space around the seed.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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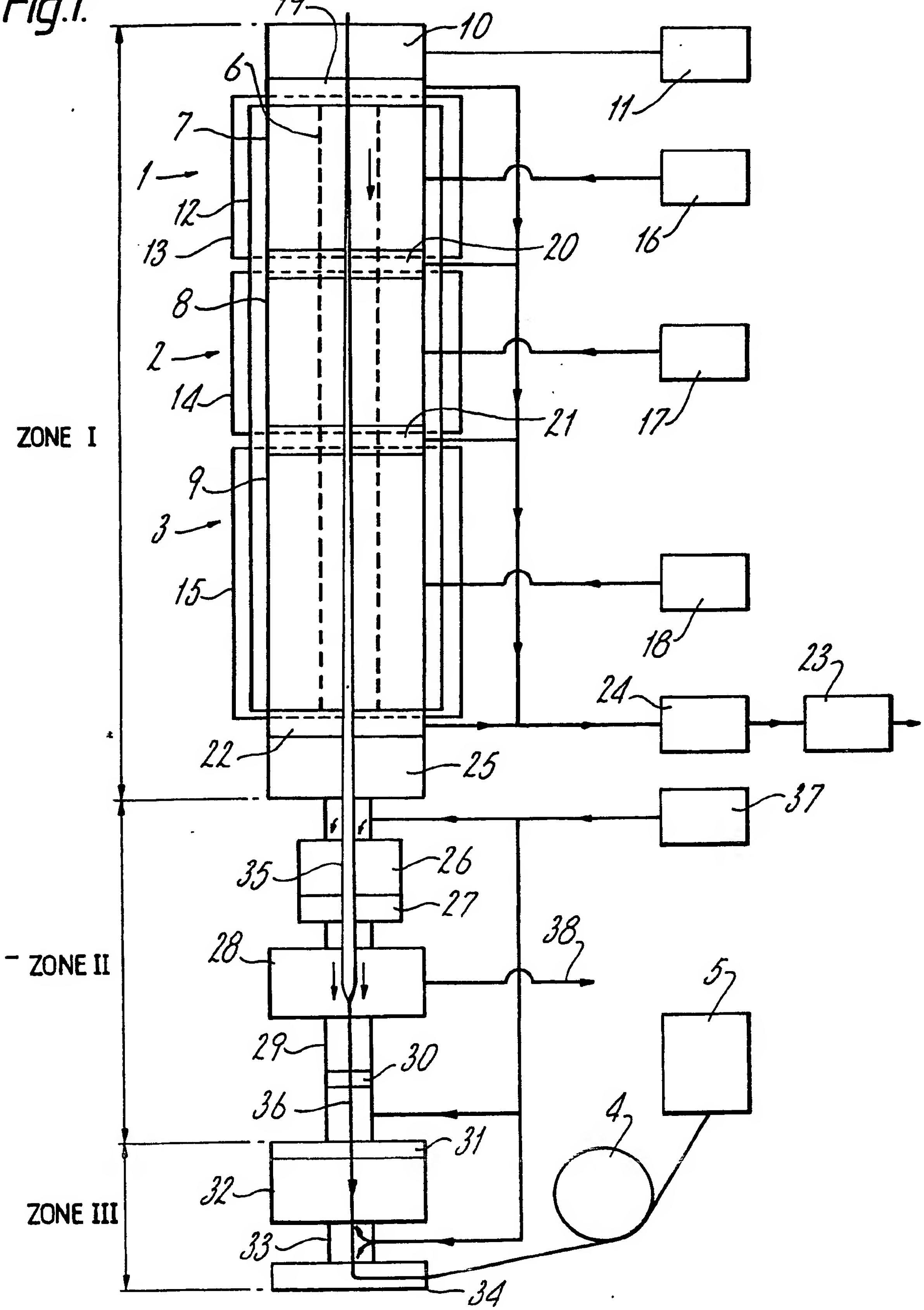
Fig.1.



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ZONE I
ZONE II
ZONE III

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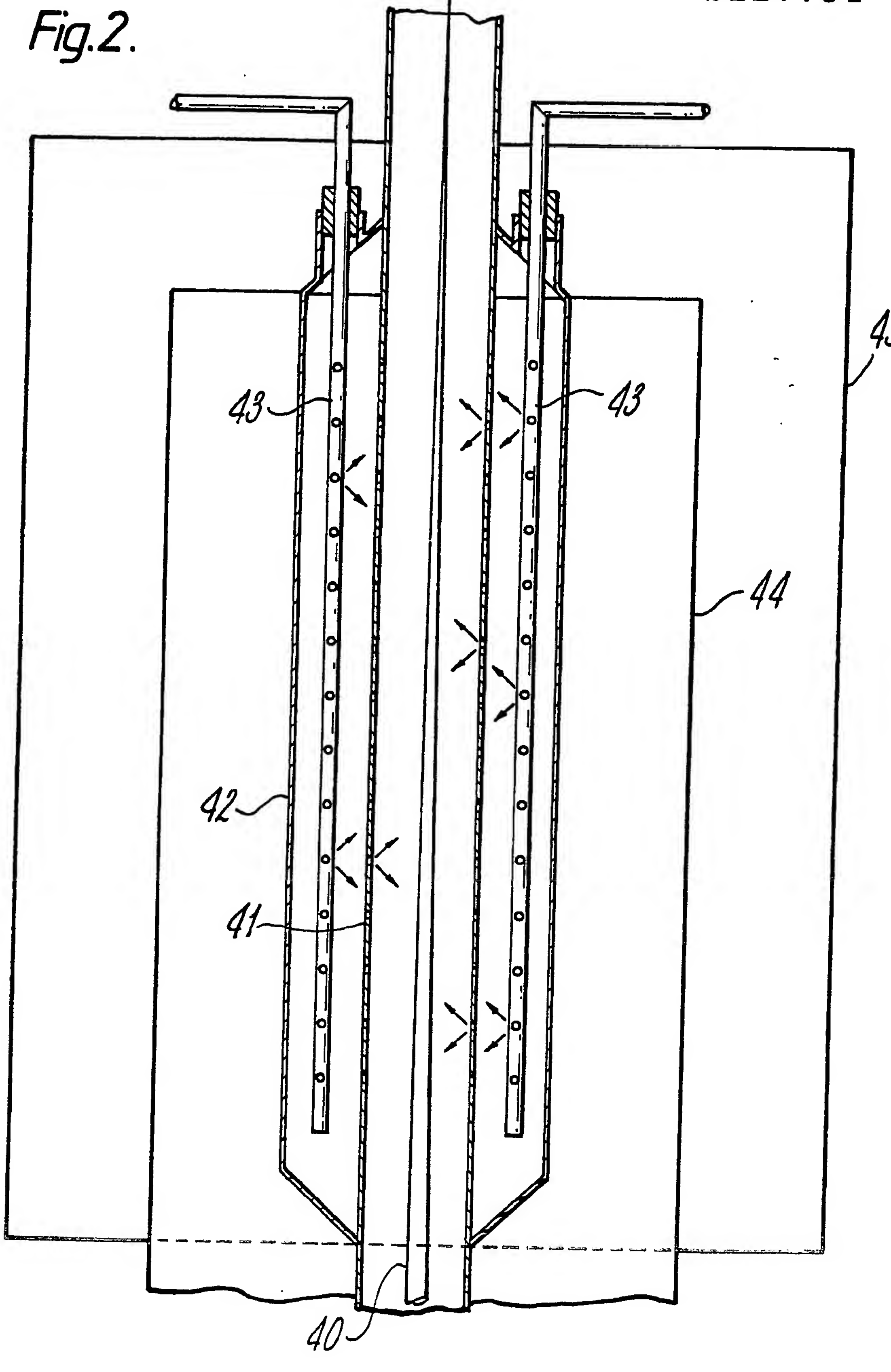
Fig.2.



SPECIFICATION

Manufacture of optical fibre waveguides

This invention relates to the manufacture of optical fibre waveguides by a process of the type (hereinafter referred to as the type specified) in which a preform is produced by depositing on a glass substrate one or more vitreous coatings, each composed essentially of one or more oxides and formed by causing a chemical reaction to take place in a gaseous mixture including oxygen and the vapour or vapours of one or more compounds such as halides, continuously flowing in contact with the substrate surface, and a glass fibre is drawn from the preform so produced. The invention also relates to apparatus for use in carrying out the process described.

Hitherto the production of the glass preform, and the drawing of the fibre therefrom, have been carried out in two separate procedures, and it has only been possible to produce fibres of limited lengths, determined by the dimensions of the preforms.

It is an object of the present invention to provide a process of the type specified for the manufacture of a glass optical fibre, in which process the steps of depositing the vitreous reaction product, or products, to produce a preform, and drawing the fibre from the preform, are effected successively and continuously, so that the previous limitations on the length of fibre produced can be reduced or eliminated.

According to the invention, a continuous process for the manufacture of a glass optical fibre comprises feeding an elongate glass seed core through a tubular arrangement constituting a first zone in which a glass coating is deposited on the seed core, or two or more glass coatings of different compositions are deposited successively on the seed core as it passes through successive longitudinal sections of said first zone, to produce a continuous elongate preform, and feeding the coated seed core through a second zone in which the said preform is heated and drawn to fibre, and in the said first zone the seed core passes along the axis of an inner tube which has a multiplicity of perforations through its wall and which is surrounded coaxially by an outer tube or two or more successive outer tube sections, a first annular space being provided between the seed core and the inner tube and a second annular space being provided between the inner tube and the outer tube or each outer tube section, and the deposition of the glass coating in said first zone, or of each of two or more successive coatings in respective longitudinal sections of said first zone, is effected by passing a gaseous reaction mixture consisting of oxygen, the vapour or vapours of one or more compounds capable of reacting with oxygen to produce the desired coating material, and optionally an additional carrier gas, continuously from the or each said second annular space through said perforations into said first annular space, and causing a chemical reaction or reactions to take place continuously in the gaseous mixture in said first annular space by generating energy in said space, while heat is applied to the whole length of said first zone, the conditions of energy level, temperature and gas pressure in said first zone being so controlled that a glass coating composed essentially of one or more oxides is formed continuously on the whole of the surface of the seed core in said first zone or in each said longitudinal section thereof.

Gaseous reaction products and any residual gaseous reaction mixture are withdrawn continuously from the space within the perforated tube in the first, deposition, zone, or from the said space in each section of the deposition zone.

Glass optical fibres are usually coated with synthetic resin, either to provide protection for the fibre or, in some cases, to form a plastic cladding constituting part of the waveguide structure. In the process of the invention, the drawn fibre is preferably passed continuously from the said second zone in which it is drawn, through a third zone in which a resin coating is applied and cured; if desired, two or more coats of the same resin, or of different resins, may be applied. The resin-coated fibre, after cooling, may then be passed continuously around a capstan which is rotated at a desired speed for effecting drawing of the fibre, and thence to packaging means: thus the fibre may be wound on a reel, or coiled to form a flat package or a dispenser package. Alternatively, the coated fibre may be fed, via the capstan, directly to a cable manufacturing assembly line, to be incorporated in a cable without intermediate packaging.

A preferred form of apparatus for the manufacture of a resin-coated glass optical fibre by the process of the invention comprises a first, deposition, zone which includes an inner tube having a multiplicity of perforations through its wall, an outer tube disposed coaxially with the inner tube, or two or more outer tube sections respectively disposed coaxially with contiguous longitudinal sections of the inner tube, an annular space being provided between the inner tube and the outer tube or each outer tube section, means for introducing a gaseous reaction mixture into the said space between the inner and outer tubes or separate means for introducing a gaseous reaction mixture into each of the spaces between the inner tube and the respective outer tube sections, means for removing gaseous reaction product and residual gaseous reaction mixture from the inner tube or from each said longitudinal section thereof, an energy excitation source located so as to generate energy in the space within the inner perforated tube, and heating means located outside the outer tube or tube sections; a second, drawing, zone which is contiguous with the deposition zone and includes a tubular furnace located so as to receive the glass preform emerging from the deposition zone, to heat the preform to a sufficiently high temperature to enable fibre to be drawn therefrom, and a region maintained at a lower temperature for cooling the drawn fibre; a third, coating, zone which is contiguous with the drawing zone and includes means for applying at least one coating of synthetic resin on to the drawn fibre and means for curing the said coating, or each said coating; and means for drawing the fibre and for driving the seed core,

preform and fibre through the said three zones at a controlled speed.

The drive means may conveniently be located within the drawing zone, suitably between the exit end of the deposition zone and the furnace. The fibre drawing means is suitably a rotating capstan around which the resin-coated fibre passes on emerging from the coating zone, as referred to above.

The method of the invention is particularly applicable to the manufacture of an optical fibre composed of silica with one or more dopants for modifying the refractive index of the silica. For this purpose, the seed core employed is formed of vitreous silica, and the reactant vapours suitably consist of silicon tetrachloride and, for the introduction of a dopant or dopants into the coating or into one or more of the coatings, as may be required, one or more additional compounds, such as chlorides, from which the required dopant or dopants can be derived by reaction with oxygen; if desired a suitable fluorine-containing compound, such as dichlorodifluorosilane, may be included in the reaction mixture, for the introduction of fluorine as a dopant in the silica coating, instead of or in addition to an oxide dopant or dopants. The seed core employed may be a glass filament or rod. A filamentary seed may be composed of glass or silica which is not necessarily of high purity, since on drawing the fibre the initial filament is reduced to a negligible proportion of the cross-section of the fibre produced, such that its presence at the axis of the fibre will have no effect on the optical properties of the fibre. The length of the fibre produced need not be limited by the length of the initial seed core: thus the length of the seed can be extended indefinitely by joining a second length of seed on to the first length when nearly all of the latter has passed into the deposition zone, by fusing the ends of the two lengths together, and repeating this procedure with successive lengths of seed as many times as is desired. Alternatively, when the whole of the initial seed has passed into the deposition zone, deposition of the vitreous reaction product may occur progressively on the end of the seed, resulting in the continuous growth of a filamentary seed core, on which further deposition takes place throughout the remainder of the deposition zone as this seed continues to travel through the zone.

The number of longitudinal sections constituting the deposition zone will be determined by the structure of the optical fibre to be produced, the vitreous coatings deposited on the seed core in the respective sections being of different compositions with respect to the nature and/or proportion of dopant or dopants incorporated in the basic glass or silica forming the bulk of the coating, to impart a desired refractive index profile to the fibre product. For example, if the fibre is to consist of a vitreous core with a synthetic resin cladding, the core material is deposited on the seed throughout the whole of the deposition zone, the cladding being subsequently applied to the drawn fibre in the resin coating zone. For the manufacture of a fibre composed of vitreous core and vitreous cladding, the deposition zone consists of two contiguous longitudinal sections, the core material being deposited in the first section and the cladding material in the second section. If the fibre is to be composed of vitreous core, vitreous cladding, and an intermediate vitreous coating, such as a water barrier layer or buffer layer, the deposition zone consists of three contiguous longitudinal sections in which the core material, intermediate layer material, and cladding material are deposited respectively.

The required gaseous reaction mixture for forming the vitreous deposit in each section of the deposition zone is introduced into the annular space between the inner and outer tubes of that section. If the material deposited in the zone or in a section thereof is required to be of constant composition, the preformed reaction mixture is introduced directly into the said space, under sufficient pressure to ensure constant flow through the perforations in the inner tube wall, into the region of the annular space within the inner tube in which reaction and deposition take place. The rate of flow of the gaseous mixture into the reaction region in the inner tube is controlled by the number, distribution and diameters of the perforations, which are so varied along the length of the inner tube in the zone, or in each section, that the rate of flow of the gaseous mixture through the performations is increased as the diameter of the coated seed increases during its passage through the zone or section, to ensure that the rate of deposition of the coating is maintained substantially constant along the length of the zone or each section thereof.

For the formation of a coating of radially graded composition in respect of proportions of dopant or dopants, and hence of radially graded refractive index, for example in the production of an optical fibre having a graded index core, at least the reactant vapours included in the gaseous mixture are introduced separately through two or more individual perforated feed tubes inserted into the annular space between the inner and outer tubes in the deposition zone or in the appropriate section thereof. The perforations in these individual feed tubes, as well as those in the inner perforated tube, are varied in respect of number, distribution and diameters along the lengths of the tubes, so as to control the composition of the deposited material along the length of the seed in the zone or section, to give the required continuous gradation in the proportion of dopant, or of each dopant, incorporated in the coating. Each vapour constituent so introduced will usually be entrained in either oxygen or an inert carrier gas, in the latter case the oxygen also being introduced through a separate perforated feed tube.

A preferred source of energy for activating the reaction or reactions in the deposition zone in a plasma-exciting device, operated in such a manner as to produce a plasma column in the annular space between the seed core and the inner perforated tube, and to maintain the plasma column constantly extending throughout the length of the said space in the whole of the deposition zone. Preferably the device is maintained in a stationary position with respect to the inner perforated tube, suitably being located outside the outer tube. The device may be a

RF coil surrounding the whole length of the tube system forming the deposition zone, or a microwave cavity located around the outer tube, adjacent to the seed core input end of the deposition zone, and supplied with sufficient power to maintain a plasma column of the required length. The plasma can be sustained by ionisation of the oxygen included in the reaction mixture, but preferably an ionisable carrier gas, such as argon, is employed, the rate of flow of the carrier gas being somewhat greater than the flow rates of the oxygen and the reactant vapour or vapours. The use of auxiliary means, such as a Tesla coil, will usually be required to initiate the plasma.

A preferred arrangement for producing plasma excitation of the reaction or reactions consists of an asymmetrical microwave cavity located around one end of the outer tube, together with an electrically conductive tube located coaxially around the whole length of the tube system forming the deposition zone. With this arrangement, the combination of the conductive tube and the plasma column produced in operation constitutes a coaxial waveguide, along which a progressive electromagnetic wave is launched from the cavity, promoting increased extension of the plasma column for a given power input to the cavity.

In order to ensure that a plasma is produced only in the inner annular space between the seed core and the inner tube and not in the outer annular space or spaces between the inner and outer tubes, the gas pressure in the outer space or spaces must be maintained considerably higher than that in the inner space, the relative pressures being controlled by the flow rates of the gases, the arrangement of the perforations in the inner tube, and in individual gas/vapour feed tubes if present, and by continuous exhaustion of the said inner space.

To ensure the direct formation of a vitreous deposit, the gas pressure in the said inner space is maintained below 20 Torr: a pressure appreciably above 20 Torr would result in the formation of a particulate deposit, necessitating subsequent heating of the preform to vitrify the coating or coatings.

In order to avoid deposition of glass occurring on the inner tube and on the individual feed tubes, if present, it is desirable either to provide electromagnetic or electrostatic means for controlling the outer surface of the plasma column, to keep the high energy regions away from the surfaces on which deposition is to be prevented, or to ensure that the gas pressure and flow characteristics are such as to inhibit the presence of plasma in areas in which deposition is not required.

Other forms of energy excitation can be employed, as alternatives to a plasma-producing device. For example, a laser may be located adjacent to one end of the perforated inner tube, and operated in such a manner that a laser beam is directed along the interior of the said tube, so as to surround the seed.

Heating of the deposition zone provides additional energy for promoting the gaseous reaction, and is essential to maintain the seed core at a sufficiently elevated temperature to ensure the formation of a smooth, continuous vitreous coating, or coatings, on the seed: a silica seed is suitably heated to about 1000°C. The heating is conveniently achieved by enclosing the whole assembly of seed, inner perforated tube, outer tube, and conductive "waveguide" tube where this is used, in a tubular electric furnace. When the deposition zone consists of two or more longitudinal sections, separate furnaces may be provided for the respective sections.

If desired, additional energy and gaseous flow may be provided in the deposition zone by including in the gaseous reaction mixture a combustible gas, for example carbon monoxide or other gas the combustion of which will not introduce harmful contaminants into the coating, or into any of the coatings, and igniting this gas within the inner perforated tube. Ignition may take place spontaneously, if the system is raised to a sufficiently high temperature before the introduction of the combustible gas, or ignition may be effected, for example, by means of an electrode inserted through the tube system and energised by means located outside the tubular system. In the latter case, the heat generated by the gas combustion may eliminate the need for external heating of the system. In some cases such gas combustion may provide sufficient energy to activate the coating-forming reaction, without the use of any other energy excitation means. The combustible gas may be employed as the carrier gas for the reactant vapours.

In order to ensure uniform deposition of vitreous material around the whole circumference of the seed core, it may in some cases be desirable to rotate the seed about its axis throughout the process, for example if the system of seed and surrounding tubes is not perfectly concentric, or if the gases and vapours are not uniformly mixed within the inner tube.

Some specific processes in accordance with the invention will now be described by way of example, with reference to the accompanying drawings, in which

Figure 1 is a schematic representation of an apparatus lay-out suitable for the manufacture of an optical fibre having a stepped refractive index profile and consisting of a core, water-barrier layer and cladding of different silica-based compositions, and

Figure 2 shows, in part-sectional elevation, a deposition zone section designed for the formation of a graded refractive index deposit on a seed core.

The lay-out shown in Figure 1 consists essentially of a deposition zone I including three contiguous longitudinal deposition sections 1, 2 and 3, a drawing zone II, and a resin coating zone III, together with a capstan 4 and packaging means indicated by the block 5. In practice, zones II and III are each considerably longer, in relation to zone I, than is indicated in the drawing.

A perforated inner silica tube 6 extends throughout the length of the three deposition sections of zone I, and is surrounded by coaxial outer silica tubes 7, 8, 9 which define the respective sections. An asymmetric microwave cavity 10 is located at the seed inlet end of zone I, adjacent to the outer tube 7, and is supplied with power from a microwave generator 11. The outer silica tubes 7, 8, 9 are surrounded by an electrically conductive tube 12,

suitably composed of high temperature oxidation resistant steel, and the respective sections are further surrounded by tubular electric furnaces or ovens 13, 14, 15.

Separate gaseous reaction mixture feed means are provided for the respective sections of zone I, the core-forming mixture being fed into the outer silica tube 7 from a mixture preparation unit 16, the mixture required for forming the barrier layer being fed into the outer silica tube 8 from a mixture preparation unit 17, and the cladding-forming mixture being fed into the outer silica tube 9 from a mixture preparation unit 18. Exhaust outlets 19, 20, 21 and 22 are situated at both ends of the deposition zone and between the sections thereof, being so arranged that each deposition section is exhausted from both ends; the exhaust outlets are connected to a vacuum pump 23 via a trap 24 to prevent back diffusion of the exhausted gases. A sliding vacuum seal 25 is provided at the outlet end of zone I.

Zone II includes drive means 26, suitably in the form of a simple longitudinal caterpillar drive, for conveying the seed core and preform through the system at a controlled speed, means 27 for monitoring the diameter of the preform, a furnace 28 in which the preform is heated preparatory to drawing, and a section 29 in which the drawn fibre is cooled, and in which is incorporated means 30 for monitoring the diameter of the fibre.

Zone III consists of a resin coating applicator 31, a curing oven 32, a cooling region 33, and a diverter pulley 34 from which the coated fibre is conveyed to the capstan 4 and packaging unit 5. The resin coating is applied to the fibre in liquid form, either as a liquid, uncured resin or as a solution of the resin in an organic solvent; the applicator may be a bath through which the fibre passes, with a die outlet for controlling the thickness of the coating, or may consist of impregnated pads, or a grooved pulley over which the fibre passes while liquid resin is fed continuously into the groove. Additional means, such as felt pads or a die, may be provided for wiping off surplus coating and ensuring uniformity of the coating thickness, before the coated fibre enters the curing oven. The oven is of elongate tubular form.

Throughout zones II and III the preform 35 and fibre 36 are surrounded by a flowing inert atmosphere, such as dry argon, which is introduced from a source 37 into locations adjacent to the preform entry end and the fibre exit end of zone II, and into the cooling region 33 of zone III, and is exhausted from the furnace 28, as shown at 38.

In operation of the apparatus shown in Figure 1, a seed core in the form of a tapered silica rod is initially inserted through the whole of zone I, along the axis of the perforated tube 6, and into the drive mechanism 26, then the flows of the respective gaseous reaction mixtures into the pre-heated sections 1, 2 and 3 are commenced and the plasma is established throughout the length of the space within the tube 6, by means of the microwave cavity 10 and conductive tube 12. The seed may be extended in the form of a filament, or growth of the initially deposited material longitudinally on the rear end of the initial seed rod may be relied upon for continuous formation of a seed core. As the seed travels through zone I, a core layer, a water barrier layer and a cladding layer are deposited upon it successively in sections 1, 2 and 3 respectively, resulting in the continuous production of a preform, which is driven into the furnace 28. Drawing of the fibre 36 from the preform, and passage of the fibre through the resin coating means 31 and curing oven 32, are effected by rotation of the capstan 4 at a suitable speed for drawing fibre of the required diameter, the drive means 26 being synchronised with the capstan drive means (not shown) so that the rate at which the preform is fed into the furnace 28 is compatible with the required rate of drawing of the fibre.

It is preferred to initiate the process by inserting a tapered seed rod through the whole of zone I before the gas flows and plasma are established, rather than by feeding a seed of small constant diameter into the input end of the zone and through the zone simultaneously with the introduction of the gas mixtures, because the former procedure enables the gas flow conditions to be stabilised more rapidly and maintained constant. The initial length of fibre, drawn from the first portion of preform which is formed on the initial tapered seed and therefore does not include the three complete coatings, can be cut off and discarded.

In one specific example of the production of an optical fibre by the process described above with reference to Figure 1, the gaseous reaction mixture fed into section 1 or zone I consists of argon, oxygen, silicon tetrachloride, germanium tetrachloride and phosphorus oxychloride, to form a vitreous core deposit composed of silica doped with oxides of germanium and phosphorus, the mixture fed into section 2 consists of argon, oxygen, silicon tetrachloride, phosphorus oxychloride, and either difluorodichlorosilane or boron trichloride, to form a barrier layer composed of silica doped with either fluorine or boric oxide, together with a small proportion of phosphorus pentoxide, and the mixture fed into section 3 consists of argon, oxygen and silicon tetrachloride only, to form a cladding layer of pure silica.

The compositions and feed rates of the gaseous mixtures are maintained constant at pre-determined levels, and the feed rates are synchronised with the speeds of the drive mechanism 26 and the drives of the capstan 4 and the packaging unit 5, all these speeds being controlled to be compatible with the temperature at which the furnace 28 is maintained to give a desired fibre drawing rate. The rates of flow of the gaseous mixtures through the wall of the tube 6 are varied along the length of the tube in each section, being controlled by the number, distribution and diameters of the perforations in the tube wall, in such a manner as to ensure radial and longitudinal uniformity of the thickness of the coating deposited along the length of the seed in each section. The required gas pressure differential between the spaces inside and outside the tube 6, referred to above, is maintained by exhaustion of the tube 6 from the outlets 19, 20, 21 and 22.

The total length of zone I is suitably 1.0 to 1.5 metres, the required relative lengths of the deposition sections 1, 2 and 3 being determined in conjunction with the gas mixture feed rates and speed of the drive 26 to give the required deposition rates and relative thicknesses of the core, barrier and cladding layers, and to allow a suitable operational temperature of the furnace 28 to give good strain-free drawing of the fibre at a rate synchronised with the deposition rates in the three sections.

The length of the cooling section 29 in zone II is sufficient to allow the fibre to pass into the resin coating applicator 31 at a suitable temperature for obtaining a smooth, uniform, adherent coating. The required length of the curing oven 32 is determined by the speed of travel of the coated fibre therethrough and the temperature of the oven, the length being sufficient, in relation to the temperature, to ensure that the resin coat is fully cured.

The deposition section shown in Figure 2 may correspond, for example, to section 1 of Figure 1, but is designed for the deposition of graded refractive index core material on the seed 40. The section consists of an inner perforated silica tube 41, an outer silica tube 42, and a plurality of individual perforated feed tubes 43 for the introduction of different constituents of the gaseous reaction mixture. The section is surrounded by a conductive tube 44 and furnace 45; exhaust means (not shown) are provided at each end of the inner tube section, and a microwave cavity (not shown) is located around the upper end of the inner tube. Only two feed tubes 43 are shown in the drawing, but any number required may be employed. For example, four such tubes may be used for the introduction, respectively, of silicon tetrachloride vapour entrained in argon, phosphorus oxychloride vapour entrained in argon, germanium tetrachloride vapour entrained in argon, and oxygen. The numbers, distributions and diameters of the perforations in the respective feed tubes and in the inner tube 41 are varied along the lengths of the tubes in such a manner that the flow rates of the gaseous constituents are controlled to give the required radial composition gradient of the deposited material, as well as uniform thickness of the deposit along the length of the seed in the section.

A section of this form may be substituted for section 1 of Figure 1, the remainder of the apparatus and method of operation being as described above with reference to Figure 1.

CLAIMS

1. A continuous process for the manufacture of a glass optical fibre, which comprises feeding an elongate glass seed core through a tubular arrangement constituting a first zone in which a glass coating is deposited on the seed core, or two or more glass coatings of different compositions are deposited successively on the seed core as it passes through successive longitudinal sections of said first zone, to produce a continuous elongate preform, and feeding the coated seed core through a second zone in which the said preform is heated and drawn to fibre, and wherein in the said first zone the seed core passes along the axis of an inner tube which has a multiplicity of perforations through its wall and which is surrounded coaxially by an outer tube or two or more successive outer tube sections, a first annular space being provided between the seed core and the inner tube and a second annular space being provided between the inner tube and the outer tube or each outer tube section, and the deposition of the glass coating in said first zone, or of each of two or more successive coatings in respective longitudinal sections of said first zone, is effected by passing a gaseous reaction mixture consisting of oxygen, the vapour or vapours of one or more compounds capable of reacting with oxygen to produce the desired coating material, and optionally an additional carrier gas, continuously from the or each said second annular space through said perforations into said first annular space, and causing a chemical reaction or reactions to take place continuously in the gaseous mixture in said first annular space by generating energy in said space, while heat is applied to the whole length of said first zone, the conditions of energy level, temperature and gas pressure in said first zone being so controlled that a glass coating composed essentially of one or more oxides is formed continuously on the whole of the surface of the seed core in said first zone or in each said longitudinal section thereof.

2. A process according to Claim 1, wherein the drawn fibre is passed continuously from the second zone through a third zone in which one or more coatings of synthetic resin is or are applied to the fibre and cured.

3. A process according to Claim 2, wherein the resin-coated fibre, after cooling, is passed continuously around a capstan which is rotated at a desired speed for effecting drawing of the fibre, and thence either to packaging means or to a cable-manufacturing assembly line.

4. A process according to Claim 1, 2 or 3, wherein the seed core is a glass filament or rod, and wherein, for extending the length of the seed core, successive lengths of seed core are fused together end-to-end, each such fusion operation being carried out when nearly all of the preceding length of seed has passed into the said first zone.

5. A process according to Claim 1, 2 or 3, wherein the seed core is a glass filament, and when the whole of the initial seed has passed into the said first zone continuous growth of the filament is effected by progressive deposition of the glass product of said reaction on the end of the initial seed, whereby the length of the seed core is extended.

6. A process according to any preceding Claim, wherein the seed core employed is formed of vitreous silica, and the gaseous reaction mixture includes silicon tetrachloride and, as required for introducing a dopant or dopants into the silica coating, the vapour or vapours of one or more compounds from which said dopant or dopants can be derived by reaction with oxygen.

7. A process according to any preceding Claim wherein, for the manufacture of an optical fibre consisting of a vitreous core and a synthetic resin

cladding, the core material is deposited on the seed core throughout the whole length of the said first zone, and the cladding is applied to the drawn fibre in a third, resin coating, zone.

8. A process according to any of the preceding Claims 1 to 6 wherein, for the manufacture of an optical fibre consisting of a vitreous core and vitreous cladding, the said first zone consists of two contiguous longitudinal sections, and the core material and cladding material are deposited on the seed core in the first and second sections respectively.

9. A process according to any of the preceding Claims 1 to 6 wherein, for the manufacture of an optical fibre consisting of a vitreous core, vitreous cladding, and an intermediate vitreous layer, the said first zone consists of three contiguous longitudinal sections, and the core material, intermediate layer material and cladding material are deposited on the seed core in the first, second and third sections respectively.

10. A process according to any preceding Claim, wherein the rate of flow of the gaseous reaction mixture through the perforations in the inner tube wall into the said first annular space is so controlled by the number, distribution and diameters of the said perforations that the said rate is increased as the diameter of the coated seed increases during its passage through the said first zone or each section thereof, so as to ensure that the rate of deposition of the coating is maintained substantially constant along the length of said first zone or of each section thereof.

11. A process according to any preceding Claim wherein, for depositing a coating of constant composition on the seed core in the said first zone or in a section thereof, the gaseous reaction mixture is introduced directly into the said second annular space under sufficient pressure to ensure constant flow through the perforations in the inner tube wall.

12. A process according to any of the preceding Claims 1 to 10 wherein, for depositing a coating of radially graded composition, in respect of proportions of dopant or dopants, on the seed core in the said first zone, or in a section thereof, at least the reactant vapours included in the gaseous mixture are introduced separately through two or more individual perforated feed tubes inserted into the said second annular space in the said zone or section, the composition of the deposited material along the length of the seed in said zone or section being controlled by the number, distribution and diameters of the perforations in said individual feed tubes and in the inner perforated tube, to give the required gradation in the proportion of dopant, or of each dopant, incorporated in the coating.

13. A process according to Claim 12, wherein each reactant vapour is entrained in an inert carrier gas, and oxygen is introduced through a separate perforated feed tube inserted into the said second annular space.

14. A process according to any preceding Claim, wherein the energy source for activating the coating-forming reaction or reactions in the said first zone is a plasma-exciting device, operated in such a manner as to produce a plasma column in the said first annular space between the seed core and the inner perforated tube, and to maintain the plasma column constantly extending throughout the length of the said space in the whole of the said first zone.

15. A process according to Claim 14, wherein the plasma-exciting device is maintained in a stationary position with respect to the inner perforated tube.

16. A process according to Claim 14 or 15, wherein the plasma-exciting device is a RF coil surrounding the whole length of the tube system constituting the said first zone.

17. A process according to Claim 14 or 15, wherein the plasma-exciting device is a microwave cavity located around the outer tube, adjacent to the seed core input end of the said first zone.

18. A process according to Claim 17, wherein the microwave cavity is the asymmetrical type, and an electrically conducting tube is located coaxially around the whole length of the tube system constituting the said first zone, the arrangement of the microwave cavity and the conductive tube being such that the combination of the conductive tube and the plasma column produced in operation constitutes a coaxial waveguide, along which a progressive electromagnetic wave is launched from the cavity.

19. A process according to any of the preceding Claims 14 to 18, wherein the gas pressure in the said second annular space or spaces between the inner and outer tubes in the said first zone is maintained higher than that in the said first annular space between the seed core and the inner perforated tube, by control of the flow rates of the gases and by continuous exhaustion of the said first annular space.

20. A process according to Claim 19, wherein, for ensuring the direct formation of a vitreous coating on the seed core, the gas pressure in the said first annular space is maintained below 20 Torr.

21. A process according to any of the preceding Claims 1 to 13, wherein the energy source for activating the coating-forming reaction or reactions in the said first zone is a laser located adjacent to one end of the perforated inner tube, and operated in such a manner that a laser beam is directed along the interior of the said tube, so as to surround the seed core.

22. A process according to any preceding Claim, wherein heat is applied to the said first zone by means of a tubular electric furnace surrounding the whole of the tube system constituting the said zone, or a plurality of tubular electric furnaces respectively surrounding the longitudinal sections of said zone.

23. A process according to any preceding Claim, wherein at least part of the energy required for activating the coating-forming reaction or reactions in the said first zone is provided by including a combustible gas in the gaseous reaction mixture, and igniting the said gas within the perforated inner tube.

24. A process according to Claim 23, wherein the combustible gas employed is carbon monoxide.

25. A process according to Claim 23 or 24, wherein the combustible gas constitutes a carrier gas for the reactant vapour or vapours.

26. A process according to any preceding Claim, wherein the seed core is rotated about its axis throughout the deposition process.

27. Apparatus for the manufacture of a resin-coated glass optical fibre by a process according to Claim 2, comprising a first, deposition, zone which includes an inner tube having a multiplicity of perforations through its wall, an outer tube disposed coaxially with the inne tube, or two or more outer tube sections respectively disposed coaxially with contiguous longitudinal sections of the inner tube, an annular space being provided between the inner tube and the outer tube or each outer tube section, means for introducing a gaseous reaction mixture into the said space between the inner and outer tubes or separate means for introducing a gaseous reaction mixture into each of the spaces between the inner tube and the respective outer tube sections, means for removing gaseous reaction products and residual gaseous reaction mixture from the inner tube or from each said longitudinal section thereof, an energy excitation source located so as to generate energy in the space within the inner perforated tube, and heating means located outside the outer tube or tube sections; a second, drawing zone which is contiguous with the deposition zone and includes a tubular furnace located so as to receive the glass preform emerging from the deposition zone, to heat the preform to a sufficiently high temperature to enable fibre to be drawn therefrom, and a region maintained at a lower temperature for cooling the drawn fibre; a third, coating, zone which is contiguous with the drawing zone and includes means for applying at least one coating of synthetic resin on to the drawn fibre and means for curing the said coating, or each said coating; and means for drawing the fibre and for driving the seed core, preform, and fibre through the said three zones at a controlled speed.

28. Apparatus according to Claim 27, wherein the said driving means is located within the said second zone.

29. Apparatus according to Claim 27 or 28, wherein the fibre drawing means is a rotating capstan around which the resin-coated fibre passes on emerging from the said third zone.

30. Apparatus according to Claim 27, 28 or 29, wherein the perforations in the said inner tube are varied in respect of number, distribution and diameters, along the length of the tube, to control the rate of flow of the gaseous reaction mixture through the perforations along the length of the deposition zone or of each section thereof.

31. Apparatus according to Claim 27, 28, 29 or 30, which includes two or more individual perforated tubes, inserted into the annular space between the inner tube and the outer tube, in said deposition zone or at least one section thereof, for the separate introduction of two or more reactant vapours and possibly oxygen, the perforations in each individual feed tube being varied in respect of number, distribution and diameters along the length of the tube, so as to control the composition of the deposited coating material along the length of said zone or section.

32. Apparatus according to Claim 27, substantially as shown in, and as hereinbefore described with reference to, Figure 1 or Figure 2 of the accompanying drawings.

33. A continuous process according to Claim 1 for the manufacture of an optical fibre, substantially as hereinbefore described by way of example with reference to Figure 1 or Figure 2 of the accompanying drawings.

34. An optical fibre manufactured by a process according to any of the preceding Claims 1 to 26 and 33.

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